MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2022/2023 (TERM ID 2240)

ETM7136 – DIGITAL COMMUNICATION SYSTEMS AND DESIGN

(M.Eng.Tele)

9 FEBRUARY 2023
9.30 a.m. – 12.30 p.m.
(3 Hours)

INSTRUCTIONS TO STUDENTS

1. This examination paper consists of **7 printed pages** (including the cover page) with **4 questions only.**

2. **Attempt ALL questions.** All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided. **Show all relevant steps** to obtain maximum marks.

Question 1

(a) Fig. Q1 shows the simplified block diagram of a digital communication system

(i) State any three advantages a digital communication system. [3 marks]

(ii) Sketch and briefly explain the functionality of the sub-components of the ***receiver*** block. [6 marks]

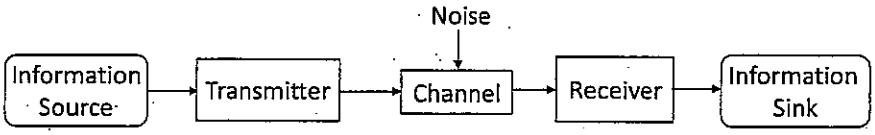

Fig. Q1

(b) Obtain and sketch the magnitude spectrum of the following switched sinusoid

$$w(t)=\prod\left(\frac{t}{T}\right)A\sin 2\pi f_0 t \text{, where } \prod\left(\frac{t}{T}\right)=\begin{cases}1, & |t|\le T/2\\ 0, & |t|>T/2\end{cases}.$$

Useful Fourier transform pairs and theorems can be found in the Appendix.

[7 marks]

(c) (i) Briefly describe and distinguish the three terms: convolution, cross-correlation and auto-correlation. [3 marks]

(ii) Obtain and sketch the auto-correlation function $R_x(\tau)=\int_{-\infty}^{\infty}x(t)x(t+\tau)dt$ of the signal $x(t)=\prod\left(\frac{t}{T}\right)$. [3 marks]

(d) A communication channel has a signal-to-noise ratio (SNR) of 36 dB and passes signals over the frequency range of 4 MHz to 6 MHz. Calculate the theoretical channel capacity. [3 marks]

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Question 2

(a) Fig. Q2.1 shows the spectrum of a bandlimited analogue signal with $B = 1000$ Hz.

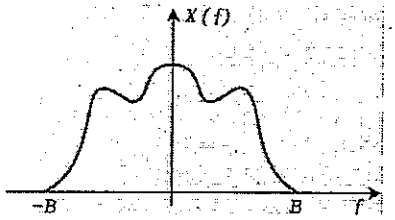

Fig. Q2.1

(i) Sketch the spectrum of a sampled version of this signal if instantaneous sampling is performed at a rate $f_s = 2200$ Hz. [2.5 marks]

(ii) Show how in the frequency domain, whether the original analog signal can be retrieved from the sampled signal obtained with $f_s = 2200$ Hz. Justify if aliasing distortion occurs. [3 marks]

(iii) Repeat part (a)(i) by replacing f_s with 1800 Hz. [2.5 marks]

(iv) Repeat part (a)(ii) by replacing f_s with 1800 Hz. [3 marks]

(b) A signal is pulse code modulated (PCM) and transmitted using binary waveforms over a channel which is bandlimited to 1 MHz. Assume that 32 quantization levels are used and that the overall equivalent transfer function is of the raised cosine type with roll-off $r = 0.3$.

(i) Determine the maximum bit rate that can be used by this system without introducing intersymbol interference. [2 marks]

(ii) Calculate the maximum bandwidth of the original analog signal that can be accommodated with these parameters. [2 marks]

(c) (i) Define line code and state its functionality. [2 marks]

(ii) Briefly describe the relationship between symbol rate and bit rate in a digitally modulated signal or a line code. [3 marks]

(d) (i) Define the correlator/integrate-and-dump circuit and state its functionality. [2 marks]

(ii) For rectangular received pulses shown in Fig. Q2.2, sketch the output of a correlator. [3 marks]

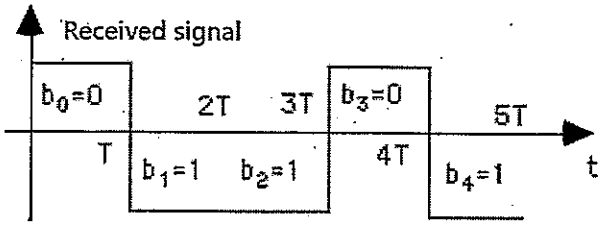

Fig. Q2.2

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Question 3

(a) Consider three digital modulation schemes: binary phase-shift keying (BPSK), quadrature PSK (QPSK), and 8PSK.

(i) Sketch their constellation diagrams. [3 marks]

(ii) Justify and identify the digital modulation scheme with the highest bandwidth efficiency. [2 marks]

(iii) Justify and identify the digital modulation scheme with the highest power efficiency. [2 marks]

(b) A binary baseband signal is passed through a raised cosine-rolloff filter with a 50% roll-off factor and is then modulated onto a carrier. The data rate is 200 kbits/s. Evaluate the following:

(i) The bandpass bandwidth of a resulting BPSK signal. [2 marks]

(ii) The bandpass bandwidth of a resulting 8PSK signal. [2 marks]

(iii) The approximate bandwidth (by applying Carson's rule) of a resulting binary frequency-shift keying (BFSK) signal when the mark frequency is 0.95 MHz and the space frequency is 1.05 MHz. [3 marks]

(c) Orthogonal frequency-division multiplexing (OFDM) is a digital multi-carrier modulation scheme widely used in communication systems.

(i) Give TWO examples of modern communication systems that use OFDM. [1 mark]

(ii) With the aid of diagrams, briefly describe the basic principle of OFDM. [6 marks]

(iii) With the aid of a diagram, briefly describe the rationale for using cyclic prefix in OFDM systems. [4 marks]

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Question 4

(a) Briefly describe with the aid of a diagram, the two main categories of forward error correction (FEC) codes. Give examples for each category of FEC code along with their applications. [6 marks]

(b) Given the following (2, 5) linear block code:

Information	Codeword
00	11110
01	01011
10	00000
11	10101

(i) State whether the code is a systematic or a non-systematic code. [1 mark]

(ii) Determine the total number of possible received codewords. [1 mark]

(iii) Determine the total number of invalid codewords. [1 mark]

(iv) Explain whether undetectable errors can occur in this code. [1 mark]

(v) Explain whether this code can recover the information bits correctly in the presence of undetectable errors. [1 mark]

(c) Consider the convolutional encoder shown in Figure Q4.1, where D denotes a unit-delay element, and MSB and LSB refer to the most and least significant bits, respectively.

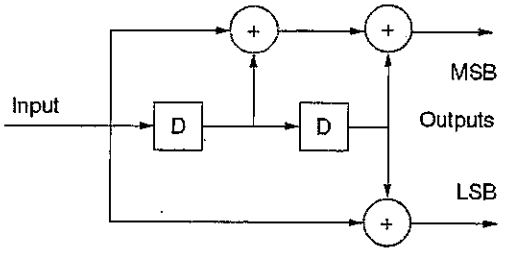

Figure Q4.1

(i) Determine the constraint length and code rate of this code. [2 marks]

(ii) Obtain and sketch the state diagram of this code. [3 marks]

(ii) Obtain and sketch one stage of the trellis diagram of this code. [3 marks]

(d) Consider a channel encoder shown in Figure Q4.2, where the block labelled with 'π' is a data interleaver. Name this type of code and briefly describe with a simple block diagram of its corresponding decoder, how it can significantly outperform conventional schemes with only one component encoder. [6 marks]

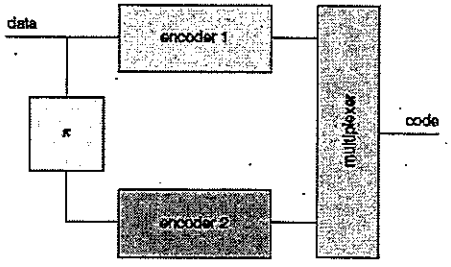

Figure Q4.2

End of Questions

Appendix I: Fourier Transform Pairs

Pair Number	$x(t)$	$X(f)$
1.	$\Pi\left(\frac{t}{\tau}\right)$	$\tau \operatorname{sinc} \tau f$
2.	$2W \operatorname{sinc} 2Wt$	$\Pi\left(\frac{f}{2W}\right)$
3.	$\Lambda\left(\frac{t}{\tau}\right)$	$\tau \operatorname{sinc}^2 \tau f$
4.	$\exp(-\alpha t)u(t),\ \alpha > 0$	$\frac{1}{\alpha + j2\pi f}$
5.	$t \exp(-\alpha t)u(t),\ \alpha > 0$	$\frac{1}{(\alpha + j2\pi f)^2}$
6.	$\exp(-\alpha\|t\|),\ \alpha > 0$	$\frac{2\alpha}{\alpha^2 + (2\pi f)^2}$
7.	$e^{-\pi(t/\tau)^2}$	$\tau e^{-\pi(f\tau)^2}$
8.	$\delta(t)$	1
9.	1	$\delta(f)$
10.	$\delta(t - t_0)$	$\exp(-j2\pi f t_0)$
11.	$\exp(j2\pi f_0 t)$	$\delta(f - f_0)$
12.	$\cos 2\pi f_0 t$	$\frac{1}{2}\delta(f - f_0) + \frac{1}{2}\delta(f + f_0)$
13.	$\sin 2\pi f_0 t$	$\frac{1}{2j}\delta(f - f_0) - \frac{1}{2j}\delta(f + f_0)$
14.	$u(t)$	$(j2\pi f)^{-1} + \frac{1}{2}\delta(f)$
15.	$\operatorname{sgn} t$	$(j\pi f)^{-1}$
16.	$\frac{1}{\pi t}$	$-j \operatorname{sgn}(f)$
17.	$\hat{x}(t) = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{x(\lambda)}{t - \lambda} d\lambda$	$-j \operatorname{sgn}(f) X(f)$
18.	$\sum_{m=-\infty}^{\infty} \delta(t - mT_s)$	$f_s \sum_{m=-\infty}^{\infty} \delta(f - mf_s),$ $f_s = T_s^{-1}$

Continued...

Appendix II: Fourier Transform Properties

Name of Theorem		
1. Superposition (a_1 and a_2 arbitrary constants)	$a_1x_1(t) + a_2x_2(t)$	$a_1X_1(f) + a_2X_2(f)$
2. Time delay	$x(t - t_0)$	$X(f)e^{-j2\pi ft_0}$
3a. Scale change	$x(at)$	$\lvert a\rvert^{-1}X\left(\frac{f}{a}\right)$
b. Time reversal	$x(-t)$	$X(-f) = X^*(f)$
4. Duality	$X(t)$	$x(-f)$
5a. Frequency translation	$x(t)e^{j\omega_0 t}$	$X(f - f_0)$
b. Modulation	$x(t)\cos\omega_0 t$	$\frac{1}{2}X(f - f_0) + \frac{1}{2}X(f + f_0)$
6. Differentiation	$\frac{d^n x(t)}{dt^n}$	$(j2\pi f)^n X(f)$
7. Integration	$\int_{-\infty}^{t} x(t')\,dt'$	$(j2\pi f)^{-1}X(f) + \frac{1}{2}X(0)\delta(f)$
8. Convolution	$\int_{-\infty}^{\infty} x_1(t - t')x_2(t')\,dt'$	$X_1(f)X_2(f)$
	$= \int_{-\infty}^{\infty} x_1(t')x_2(t - t')\,dt'$	
9. Multiplication	$x_1(t)x_2(t)$	$\int_{-\infty}^{\infty} X_1(f - f')X_2(f')\,df'$
		$= \int_{-\infty}^{\infty} X_1(f')X_2(f - f')\,df'$

End of Paper